National Semiconductor

February 1995

# LP124/LP2902/LP324 Micropower Quad Operational Amplifier

## General Description

The LP124 series consists of four independent, high gain internally compensated micropower operational amplifiers. These amplifiers are specially suited for operation in battery systems while maintaining good input specifications, and extremely low supply current drain. In addition, the LP124 has an input common mode range, and output source range which includes ground, making it ideal in single supply applications.

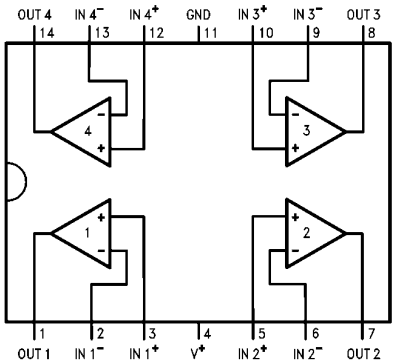
These amplifiers are ideal in applications which include portable instrumentation, battery backup equipment, and other circuits which require good DC performance and low supply current.

## Features

- Low supply current — 125 μA (max)
- Low offset voltage — 2 mV (max)
- Low input bias current — 4 nA (max)
- Input common mode to GND
- Interfaces to CMOS logic
- Wide supply range — $3V < V^+ < 32V$
- Small Outline Package available
- Pin-for-pin compatible with LM124

## Connection Diagram

**Dual-in-Line (J, N) and SO (M)**

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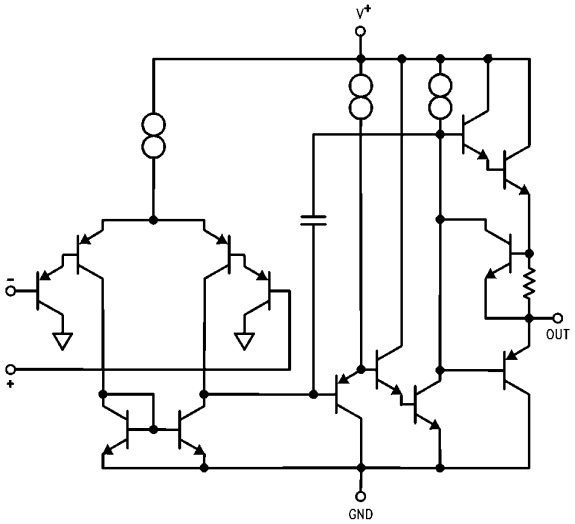
**Order Number LP124J or LP324J**
**See NS Package Number J14A**

**Order Number LP324M or LP2902M**
**See NS Package Number M14A**

**Order Number LP324N or LP2902N**
**See NS Package Number N14A**

## Simplified Schematic

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## Absolute Maximum Ratings

**If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/Distributors for availability and specifications.**

| | |
|---|---|
| Supply Voltage | 32V or ± 16V |
| LP2902 | 26V or ± 13V |
| Differential Input Voltage | 32V |
| LP2902 | 26V |
| Input Voltage (Note 1) | −0.3V to 32V |
| LP2902 | −0.3V to 26V |
| Output Short-Circuit to GND (One Amplifier) (Note 2) $V^+ \leq 15V$ and $T_A = 25°C$ | Continuous |
| ESD Susceptibility (Note 9) | ±500V |

## Operating Conditions

| | Package J | Package N | Package M |
|---|---|---|---|
| Power Dissipation (Note 3) | 500 mW | 500 mW | 500 mW |
| $T_j$ Max | 150°C | 150°C | 150°C |
| $\theta_{ja}$ | 90°C/W | 90°C/W | 140°C/W |
| Operating Temp. Range | (Note 4) | (Note 4) | (Note 4) |
| Storage Temp. Range | −65°C ≤ T ≤ 150°C | | |
| Soldering Information (10 sec.) | 300°C | 260°C | |
| Vapor Phase (60 sec.) | | | 215°C |
| Infrared (15 sec.) | | | 220°C |

## Electrical Characteristics (Note 5)

| Symbol | Parameter | Conditions | LP124 Typ | LP124 Tested Limit (Note 6) | LP124 Design Limit (Note 7) | LP2902 (Note 8) Typ | LP2902 (Note 8) Tested Limit (Note 6) | LP2902 (Note 8) Design Limit (Note 7) | LP324 Typ | LP324 Tested Limit (Note 6) | LP324 Design Limit (Note 7) | Units Limits |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $V_{os}$ | Input Offset Voltage | | 1 | 2<br>**4** | **7** | 2 | 4 | **10** | 2 | 4 | **9** | mV (Max) |
| $I_b$ | Input Bias Current | | 1 | 4<br>**8** | **8** | 2 | 20 | **40** | 2 | 10 | **20** | nA (Max) |
| $I_{os}$ | Input Offset Current | | 0.1 | 1<br>**2** | **2** | 0.5 | 4 | **8** | 0.2 | 2 | **4** | nA (Max) |
| $A_{vol}$ | Voltage Gain | $R_L = 10k$ to GND $V^+ = 30V$ | 100 | 70<br>**60** | **60** | 70 | 40 | **30** | 100 | 50 | **40** | V/mV (Min) |
| CMRR | Common Mode Rej. Ratio | $V^+ = 30V$ $0V \leq V_{cm}$ $V_{cm} < V^+ - 1.5$ | 100 | 85<br>**80** | **75** | 90 | 80 | **75** | 90 | 80 | **75** | dB (Min) |
| PSRR | Power Supply Rej. Ratio | $V^+ = 5V$ to 30V | 100 | 85<br>**80** | **75** | 90 | 80 | **75** | 90 | 80 | **75** | dB (Min) |
| $I_s$ | Supply Current | $R_L = \infty$ | 85 | 125<br>**150** | **200** | 85 | 150 | **250** | 85 | 150 | **250** | μA (Max) |
| $V_o$ | Output Voltage Swing | $I_L = 350\ \mu A$ to GND. $V_{cm} = 0V$ | 3.6 | 3.4<br>3.1 | $\mathbf{V^+ - 1.9V}$ | 3.6 | 3.4 | $\mathbf{V^+ - 1.9V}$ | 3.6 | 3.4 | $\mathbf{V^+ - 1.9V}$ | V (Min) |
| | | $I_L = 350\ \mu A$ to $V^+$ $V_{cm} = 0V$ | 0.7 | 0.8<br>**1.0** | **1.0** | 0.7 | 0.8 | **1.0** | 0.7 | 0.8 | **1.0** | V (Max) |
| $I_{out}$ Source | Output Source Current | $V_o = 3V$ $V_{in}$ (diff) = 1V | 11 | 9<br>**4** | **4** | 10 | 7 | **4** | 10 | 7 | **4** | mA (Min) |
| $I_{out}$ Sink | Output Sink Current | $V_o = 1.5V$ $V_{in}$ (diff) = 1V | 6 | 5<br>**4** | **4** | 5 | 4 | **3** | 5 | 4 | **3** | mA (Min) |
| $I_{out}$ Sink | Output Sink Current | $V_o = 1.5V$ $V_{cm} = 0V$ | 5 | 3<br>**0.5** | **1.5** | 4 | 2 | **1** | 4 | 2 | **1** | mA (Min) |
| $I_{source}$ | Output Short to GND | $V_{in}$ (diff) = 1V | 20 | 25<br>**35** | **35** | 20 | 25<br>**35** | **35** | 20 | 25<br>**35** | **35** | mA (Max) |

## Electrical Characteristics (Note 5) (Continued)

| Symbol | Parameter | Conditions | LP124 | | | LP2902 (Note 8) | | | LP324 | | | Units Limits |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Typ | Tested Limit (Note 6) | Design Limit (Note 7) | Typ | Tested Limit (Note 6) | Design Limit (Note 7) | Typ | Tested Limit (Note 6) | Design Limit (Note 7) | |
| $I_{sink}$ | Output Short to $V^+$ | $V_{in}$ (diff) = 1V | 15 | 30 **40** | **45** | 15 | 30 | **45** | 15 | 30 | **45** | mA (Max) |
| $V_{os}$ Drift | | | 7 | | | 10 | | | 10 | | | $\mu$V/C° |
| $I_{os}$ Drift | | | 5 | | | 10 | | | 10 | | | pA/C° |
| GBW | Gain Bandwidth Product | | 100 | | | 100 | | | 100 | | | KHz |
| $S_r$ | Slew Rate | | 50 | | | 50 | | | 50 | | | V/mS |

**Note 1:** The input voltage is not allowed to go more than −0.3V below $V^-$ (GND) as this will turn on a parasitic transistor causing large currents to flow through the device.

**Note 2:** Short circuits from the output to GND can cause excessive heating and eventual destruction. The maximum sourcing output current is approximately 30 mA independent of the magnitude of $V^+$. At values of supply voltage in excess of 15 $V_{DC}$, continuous short-circuit to GND can exceed the power dissipation ratings (particularly at elevated temperatures) and cause eventual destruction. Destructive dissipation can result from simultaneous shorts on all amplifiers.

**Note 3:** For operation at elevated temperatures, these devices must be derated based on a thermal resistance of $\theta_{ja}$ and $T_j$ max. $T_j = T_A + \theta_{ja}P_D$.

**Note 4:** The LP124 may be operated from $-55°C \leq T_A \leq +125°C$. The LP2902 may be operated from $-40°C \leq T_A \leq +85°C$, and the LP324 may be operated from $0°C \leq T_A \leq +70°C$.

**Note 5: Boldface numbers apply at temperature extremes.** All other numbers apply only at $T_A = T_j = 25°C$, $V^+ = 5V$, $V_{cm} = V/2$, and $R_L = 100k$ connected to GND unless otherwise specified.

**Note 6:** Guaranteed and 100% production tested.

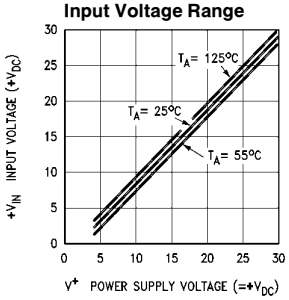
**Note 7:** Guaranteed (but not 100% production tested) over the operating supply voltage range (3.0V to 32V for the LP124, LP324, and 3.0V to 26V for the LP2902), and the common mode range (0V to $V^+ - 1.5V$), unless otherwise specified. These limits are not used to calculate outgoing quality levels.

**Note 8:** The LP2902 operating supply range is 3V to 26V, and is not tested above 26V.

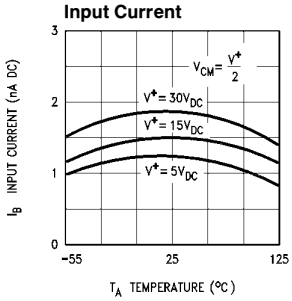
**Note 9:** The test circuit used consists of the human body model of 100 pF in series with 1500Ω.

## Typical Performance Curves

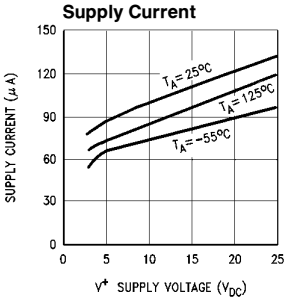
**Input Voltage Range**



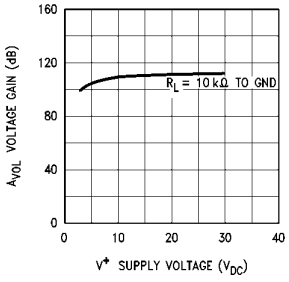

**Input Current**



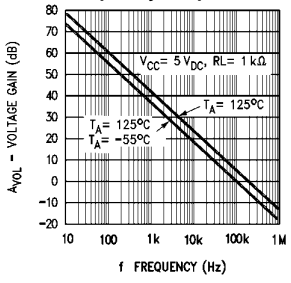

**Supply Current**



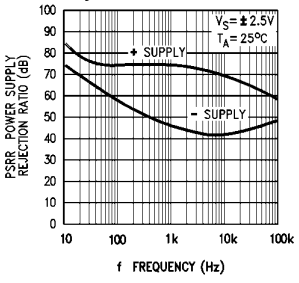

**Voltage Gain**




**Open Loop Frequency Response**




**Power Supply Rejection Ratio**

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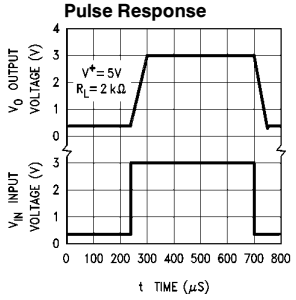
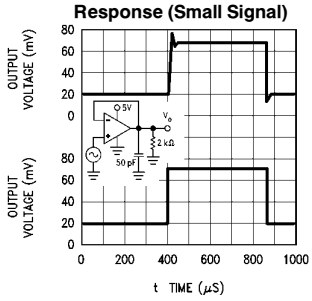
## Typical Performance Curves (Continued)

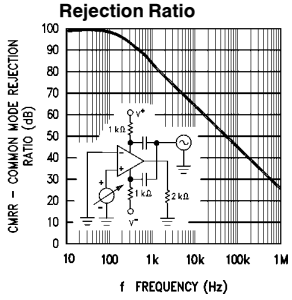
**Voltage Follower Pulse Response**




**Voltage Follower Pulse Response (Small Signal)**




**Common Mode Rejection Ratio**

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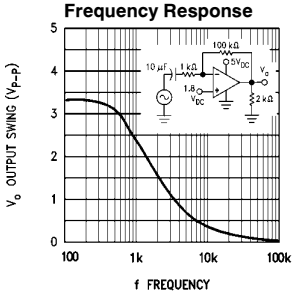
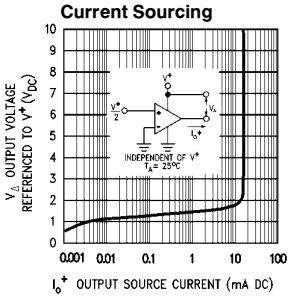
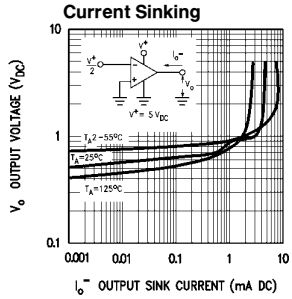
**Large Signal Frequency Response**



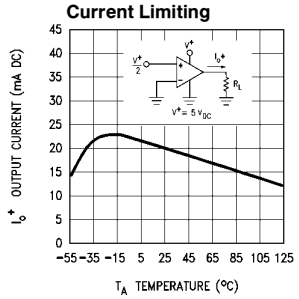

**Output Characteristics Current Sourcing**




**Output Characteristics Current Sinking**




**Current Limiting**

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## Application Hints

The LP124 series is a micro-power pin-for-pin equivalent to the LM124 op amps. Power supply current, input bias current, and input offset current have all been reduced by a factor of 10 over the LM124. Like its predecessor, the LP124 series op amps can operate on single supply, have true-differential inputs, and remain in the linear mode with an input common-mode voltage of 0 $V_{DC}$.

The pinouts of the package have been designed to simplify PC board layouts. Inverting inputs are adjacent to outputs for all of the amplifiers and the outputs have also been placed at the corners of the package (pins 1, 7, 8, and 14).

Precautions should be taken to insure that the power supply for the integrated circuit never becomes reversed in polarity or the unit is not inadvertently installed backwards in the test socket as an unlimited current surge through the resulting forward diode within the IC could destroy the unit.

Large differential input voltages can be easily accommodated and, as input differential voltage protection diodes are not needed, no large input currents result from large differential input voltages. The differential input voltage may be larger than $V^+$ without damaging the device. Protection should be provided to prevent the input voltages from going negative more than $-0.3$ $V_{DC}$ (at 25°C). An input clamp diode with a resistor to the IC input terminal can be used.

The amplifiers have a class B output stage which allows the amplifiers to both source and sink output currents. In applications where crossover distortion is undesirable, a resistor

## Application Hints (Continued)

should be used from the output of the amplifier to ground. The resistor biases the output into class A operation.

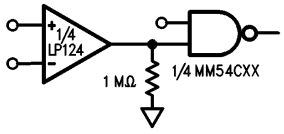
The LP124 has improved stability margin for driving capacitive loads. No special precautions are needed to drive loads in the 50 pF to 1000 pF range. It should be noted however that since the power supply current has been reduced by a factor of 10, so also has the slew rate and gain bandwidth product. This reduction can cause reduced performance in AC applications where the LM124 is being replaced by an LP124. Such situations usually occur when the LM124 has been operated near its power bandwidth.

Output short circuits either to ground or to the positive power supply should be of short time duration. Units can be destroyed, not as a result of the short circuit current causing metal fusing, but rather due to the large increase in IC chip dissipation which will cause eventual failure due to excessive junction temperatures. For example: If all four amplifiers were simultaneously shorted to ground on a 10V supply the junction temperature would rise by 110°C.

Exceeding the negative common-mode limit on either input will cause a reversal of phase to the output and force the amplifier to the corresponding high or low state. Exceeding the negative common-mode limit on both inputs will force the amplifier output to a high state. Exceeding the positive common-mode limit on a single input will not change the phase of the output. However, if both inputs exceed the limit, the output of the amplifier will be forced to a low state. In neither case does a latch occur since returning the input within the common mode range puts the input stage and thus the amplifier in a normal operating mode.

The circuits presented in the section on typical applications emphasize operation on only a single power supply voltage. If complementary power supplies are available, all of the standard op amp circuits can be used. In general, introducing a pseudo-ground (a bias voltage reference to $V^+/2$) will allow operation above and below this value in single power supply systems. Many application circuits are shown which take advantage of the wide input common-mode voltage range which includes ground. In most cases, input biasing is not required and input voltages which range to ground can easily be accommodated.

**Driving CMOS**

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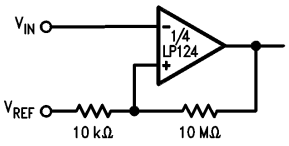
**Comparator with Hysteresis**

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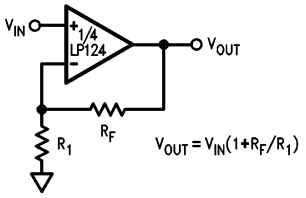
**Non-Inverting Amplifier**

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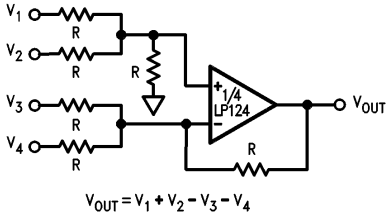
**Adder/Subtractor**

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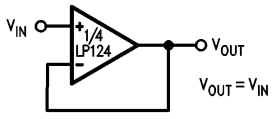
**Unity Gain Buffer**

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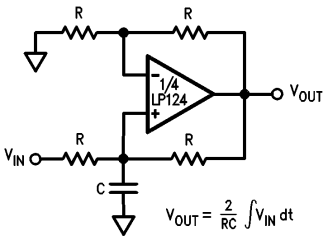
**Positive Integrator**

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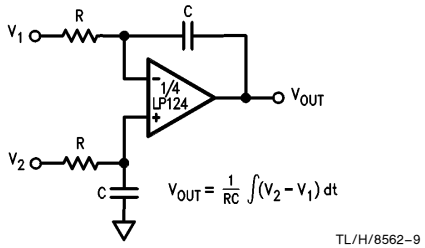
## Application Hints (Continued)

**Differential Integrator**

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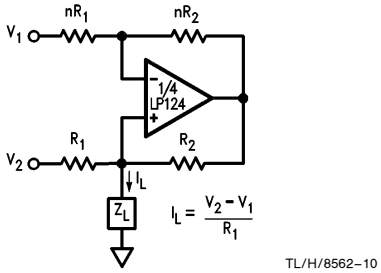
**Howland Current Pump**

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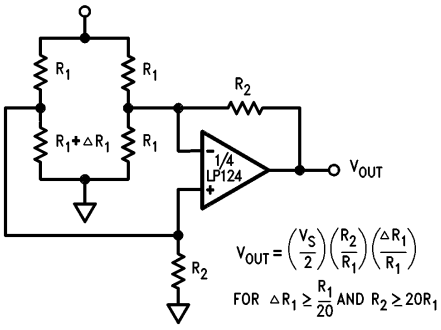
**Bridge Current Amplifier**

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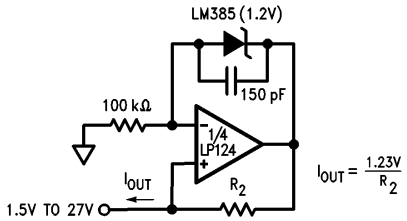
**$\mu$ Power Current Source**

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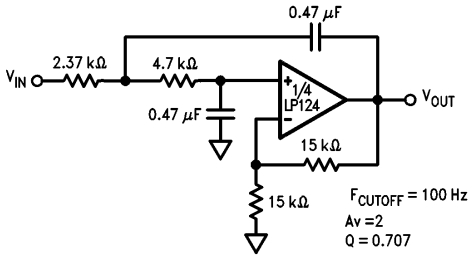
**Lowpass Filter**

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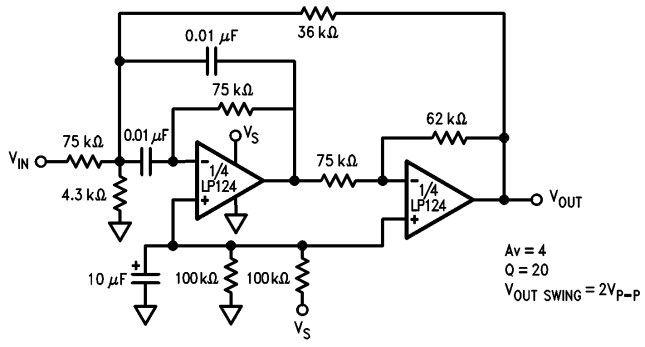
**1 kHz Bandpass Active Filter**

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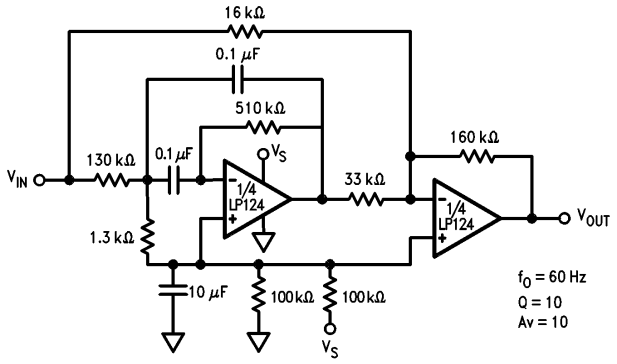
## Application Hints (Continued)

**Band-Reject Filter**

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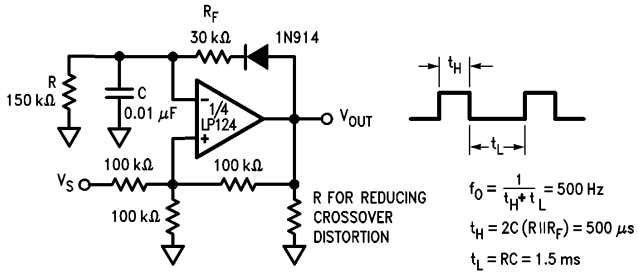
**Pulse Generator**

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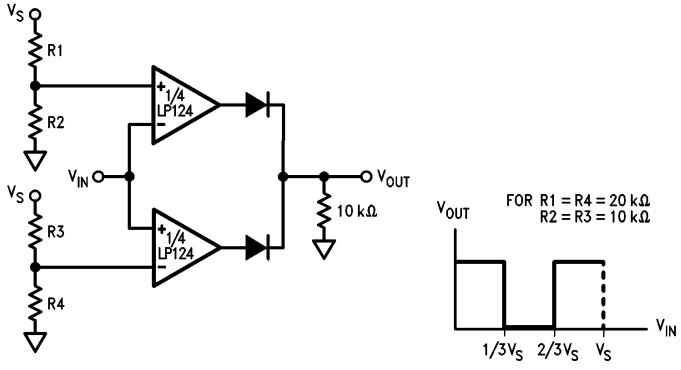
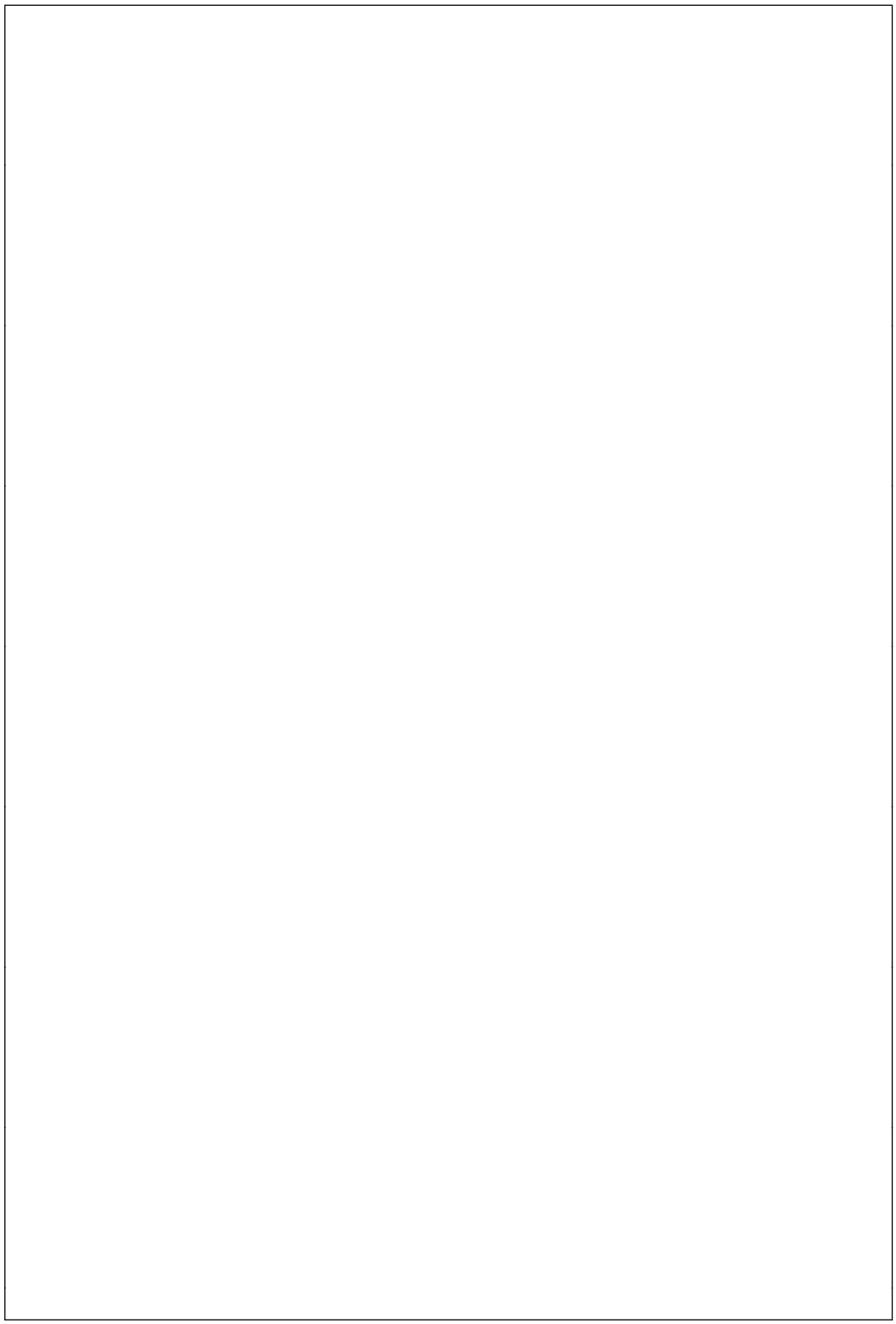
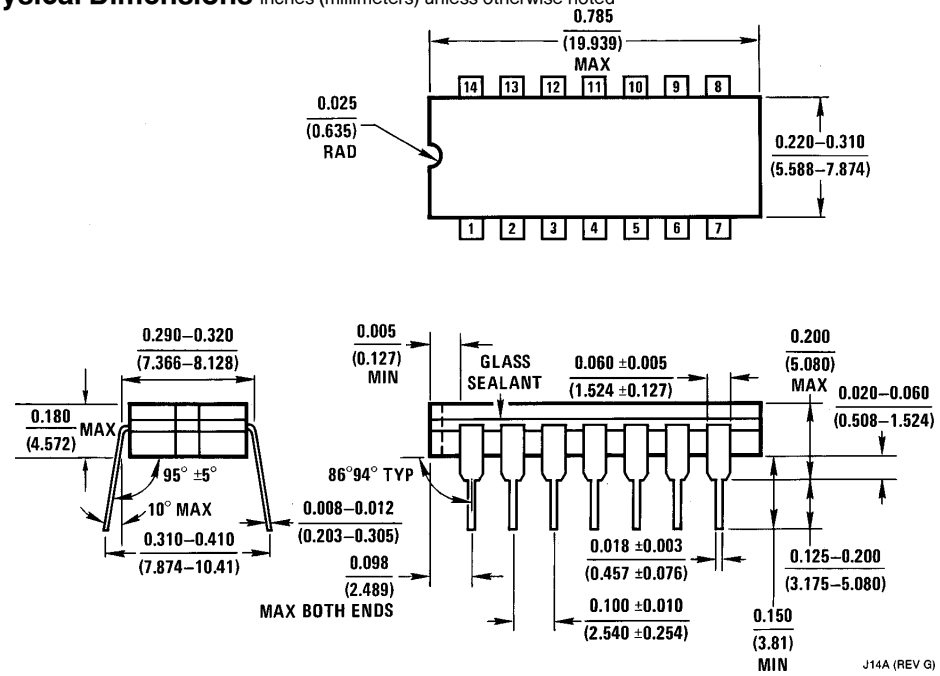
**Window Comparator**



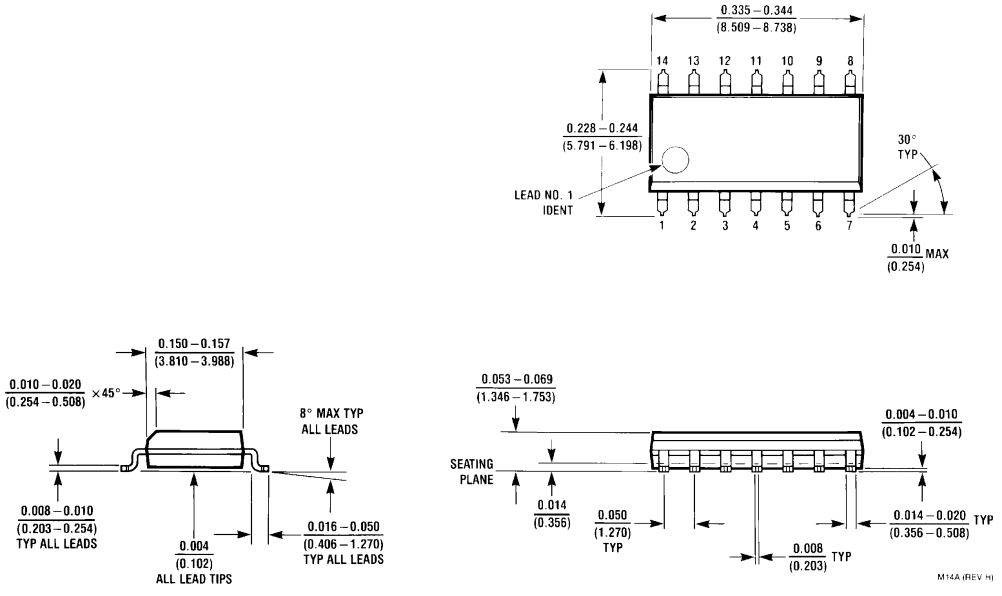

TL/H/8562–17



## Physical Dimensions inches (millimeters) unless otherwise noted



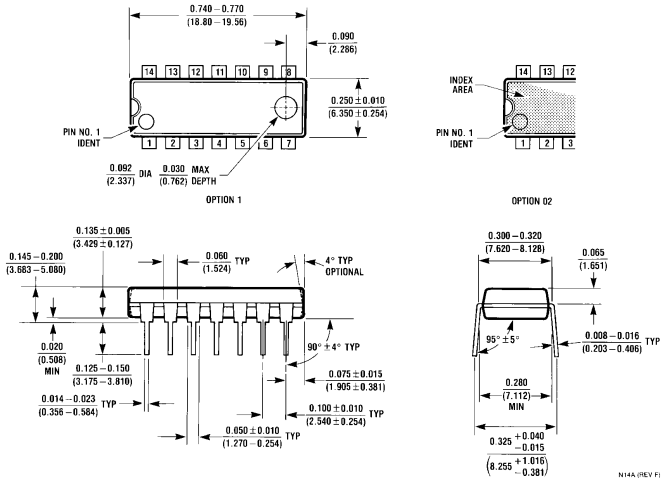

**Ceramic Dual-in-Line Package (J)**
**Order Number LP124J or LP324J**
**NS Package Number J14A**




**S.O. Package (M)**
**Order Number LP324M or LP2902M**
**NS Package Number M14A**

## Physical Dimensions inches (millimeters) unless otherwise noted (Continued)

**Lit. # 108468**




**Dual-in-Line Package (N)**
**Order Number LP324N or LP2902N**
**NS Package Number N14A**

### LIFE SUPPORT POLICY

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2. A critical component is any component of a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.

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